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Transformation of Phosphorus in Speciation and Bioavailability during Converting Poultry Litter to Biochar

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Research Problems

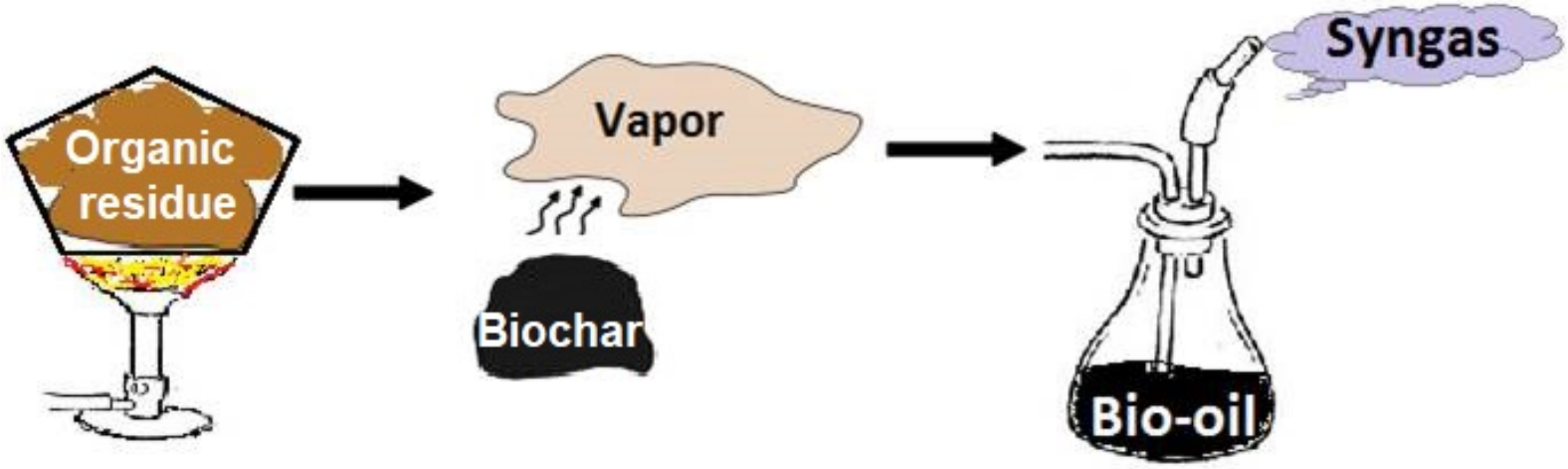
Poultry Litter
US ~12 million dry tons/yr

Research Problems

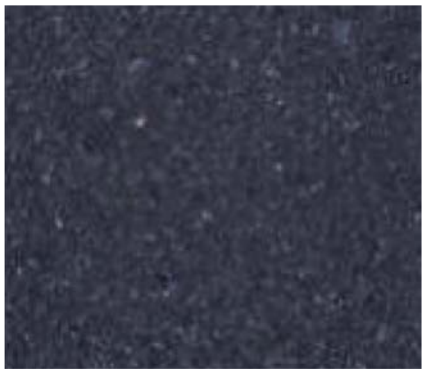
Organic fertilizer

Soil conditioner

Research Problems



Nutrient recovery?



Nutrient forms?
Availability?

Objectives

- To determine nutrient recovery when PL is converted to biochar
- To investigate transformation of P in PL during pyrolysis
- To examine the existing forms and lability of P in PL-derived biochar

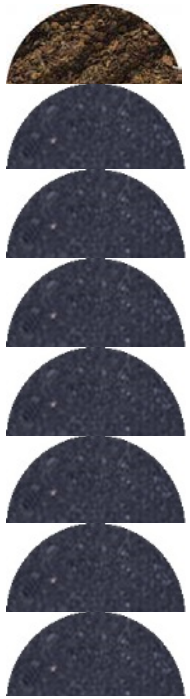
Experiments

1) Biochar generation

Complete pyrolysis at 300, 350, 400, 450, 500, 550, and 600°C

Experiments

2) Biochar characterization



Raw matter

Char300

Char350

Char400

Char450

Char500

Char550

Char600

Ground to <0.15 mm

Yield

OC content

Ash content

pH

Salinity (EC)

Nutrient contents

Specific surface area

Porosity

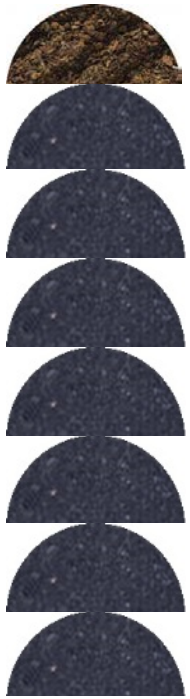
Cation exchange capacity

Surface acid functional groups

^{31}P SP/MAS NMR

Experiments

3) Biochar P analysis



Raw matter

Char300

Char350

Char400

Char450

Char500

Char550

Char600

<0.15 mm

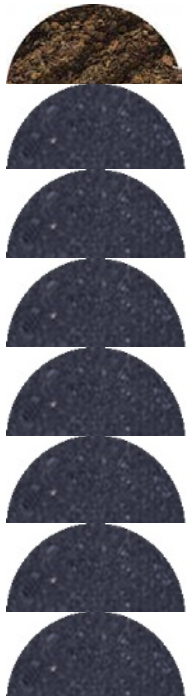
Total P

Inorganic P (1 M HCl extraction)

Organic P

Experiments

4) Biochar P extractability assessment



<0.15 mm

Batch extraction (1:50 s/sol, 24 hr) by

i. **Water**

ii. **1 M HCl**

iii. **Mehlich-3 solution**
(NH_4F + EDTA + NH_4NO_3 + HNO_3 + HA)

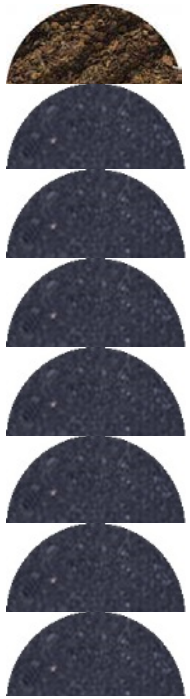
iv. **Bray-1 solution**
(0.025 M HCl in 0.03 M NH_4F)

v. **Olsen solution**
(0.5 M $NaHCO_3$, pH 8.5)

Extract P: Colorimetric method following $K_2S_2O_8$ + H_2SO_4 digestion

Experiments

5) Biochar P fractionation



<0.15 mm

Sequential extraction (1:50 s/sol, 24 hr) by

a. **Water**
b. **0.5 M $NaHCO_3$**
c. **0.1 M NaOH**
d. **1 M HCl**
e. **Residual**

Extract P: ortho-P, poly-P, and org-P by colorimetric methods

Results

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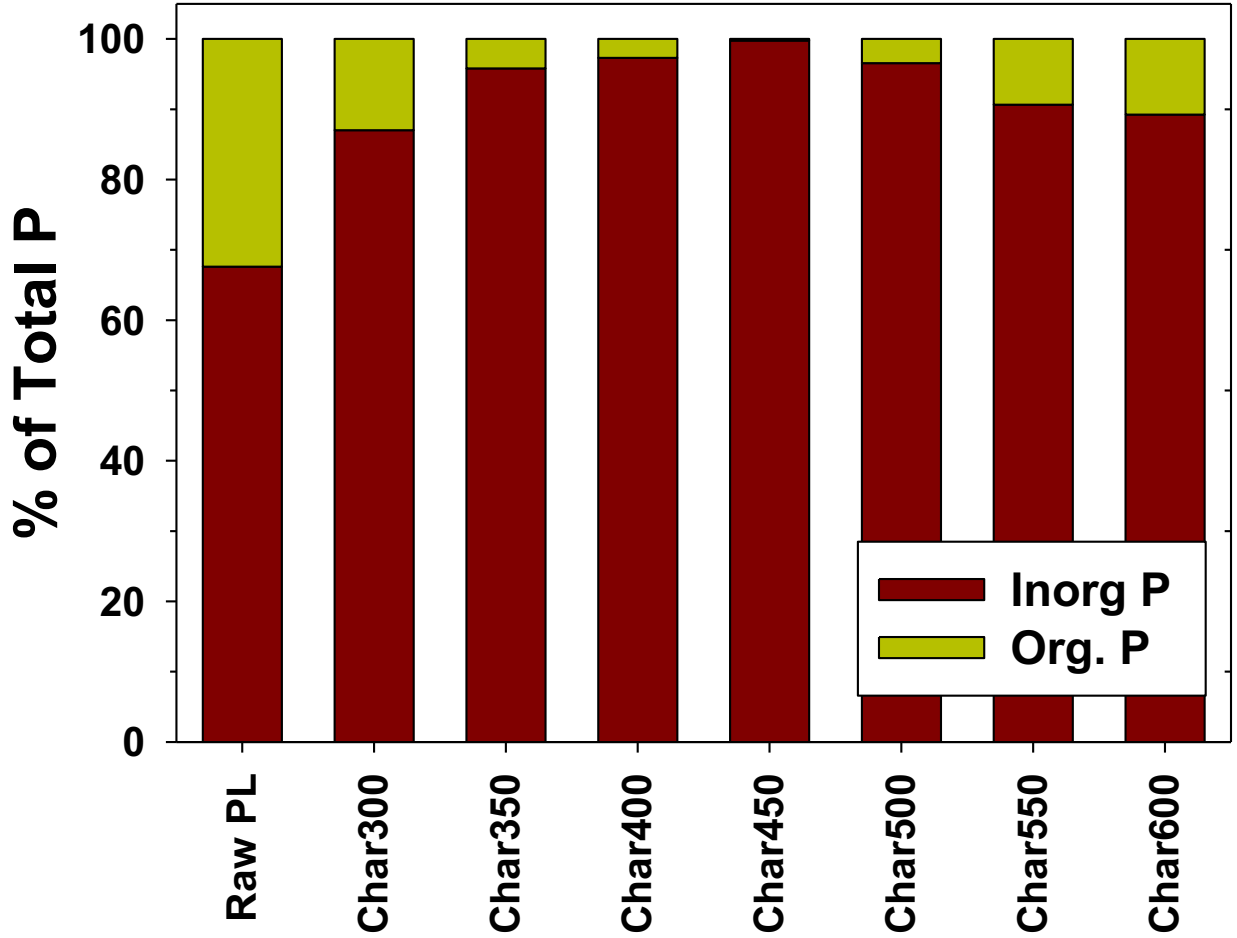
1) Nutrient recovery in biochar

Pyro. T °C	Yield %	%OC		%N		%P	
		Content	Recovery	Content	Recovery	Content	Recovery
Raw PL*	100	35.51	100	3.07	100	1.37	100
Char300	60.13	37.99	64.32	4.17	81.80	2.27	99.76
Char350	56.17	37.65	59.56	3.22	59.03	2.40	98.48
Char400	51.52	36.10	52.38	2.63	44.19	2.63	98.87
Char450	48.69	35.22	48.30	2.23	35.33	2.66	94.50
Char500	47.57	34.47	46.18	1.21	18.84	2.79	96.77
Char550	46.62	33.88	44.47	0.31	4.73	2.98	101.54
Char600	45.71	32.52	41.85	0.12	1.76	3.05	101.90

* Ash content 28.53%

Experiments

2) Transformation of poultry litter P during pyrolysis



Raw PL:

Ca 43.1 g/kg

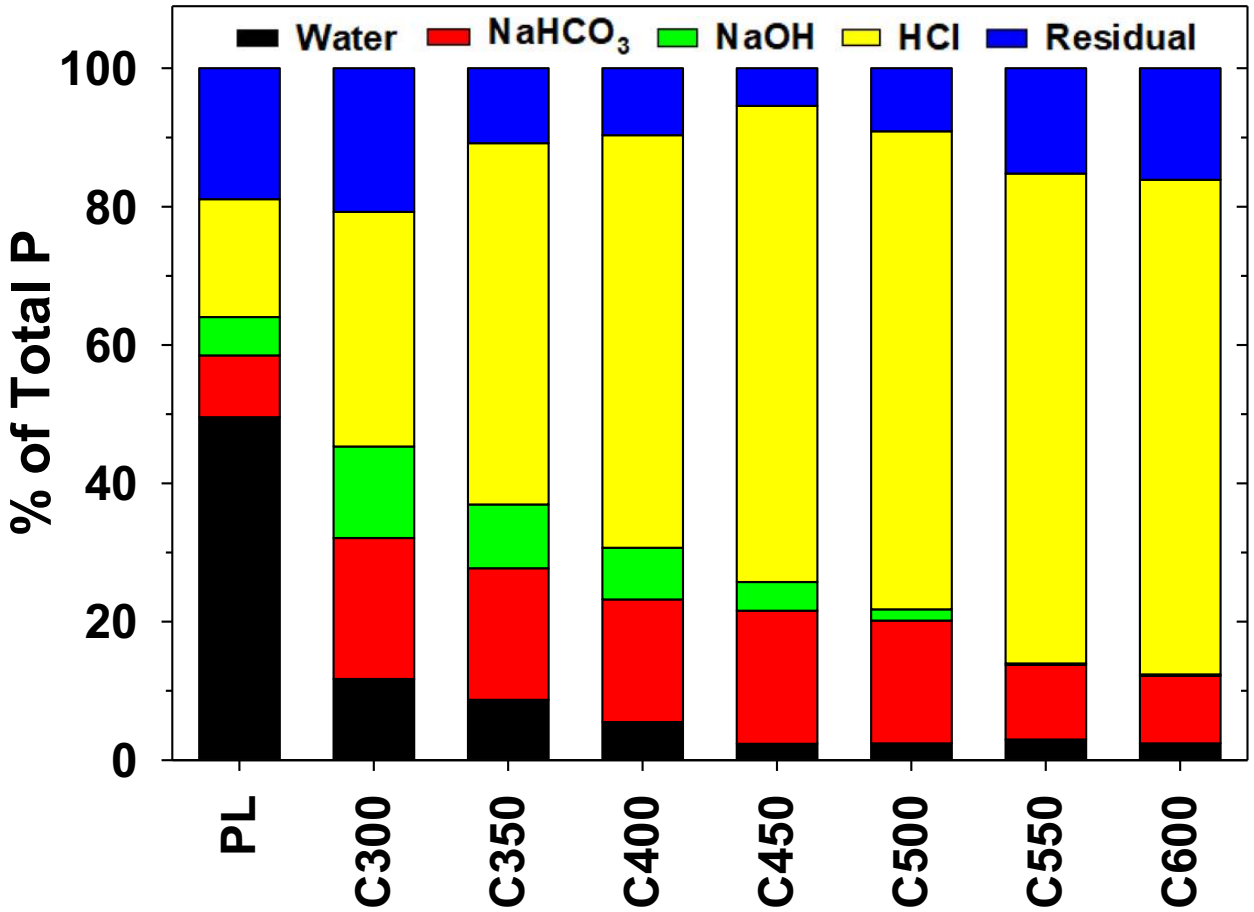
Mg 11.1 g/kg

K 41.8 g/kg

Na 18.6 g/kg

Experiments

3) Fractionation of P in biochar (by sequential extraction)



Water-extractable
Readily labile

$NaHCO_3$-extractable
Generally labile

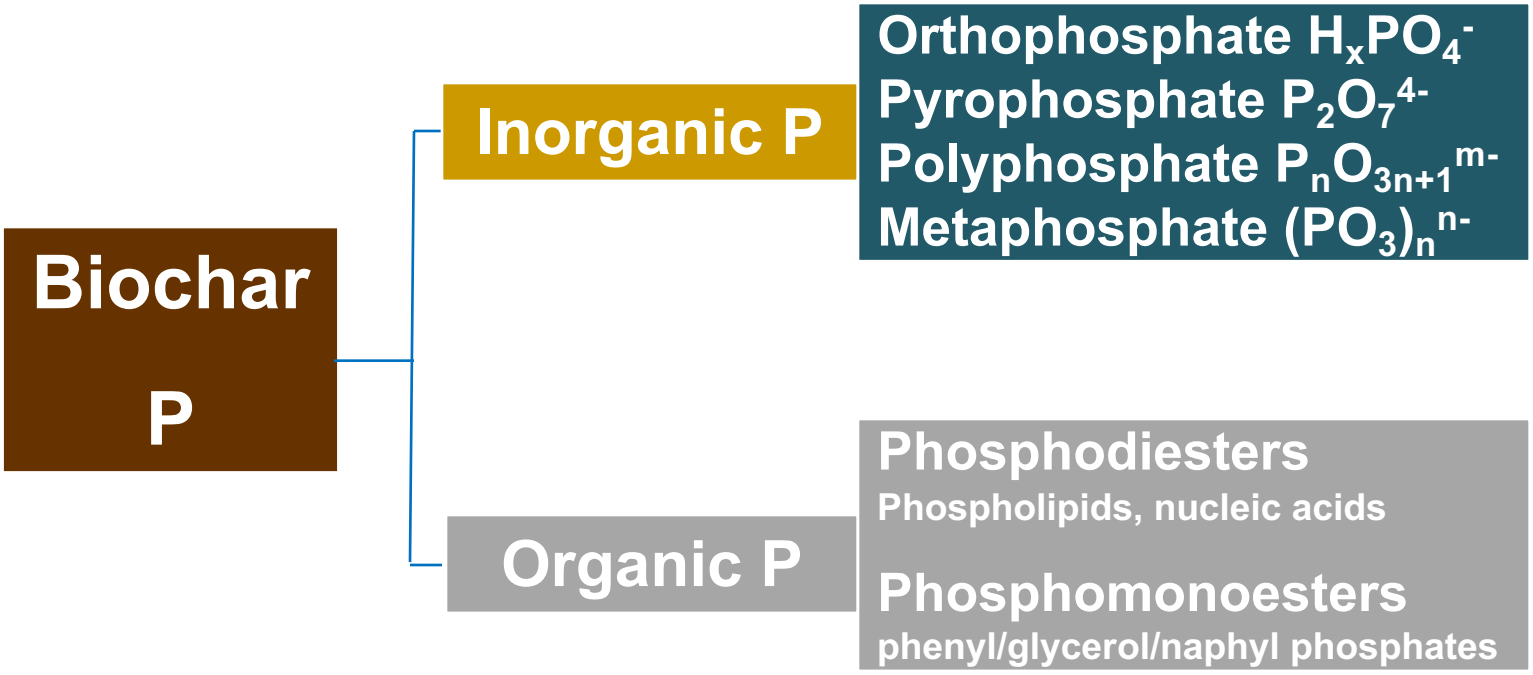
NaOH-extractable
Moderately labile

HCl-extractable
Low labile

Residual
Non-labile

Experiments

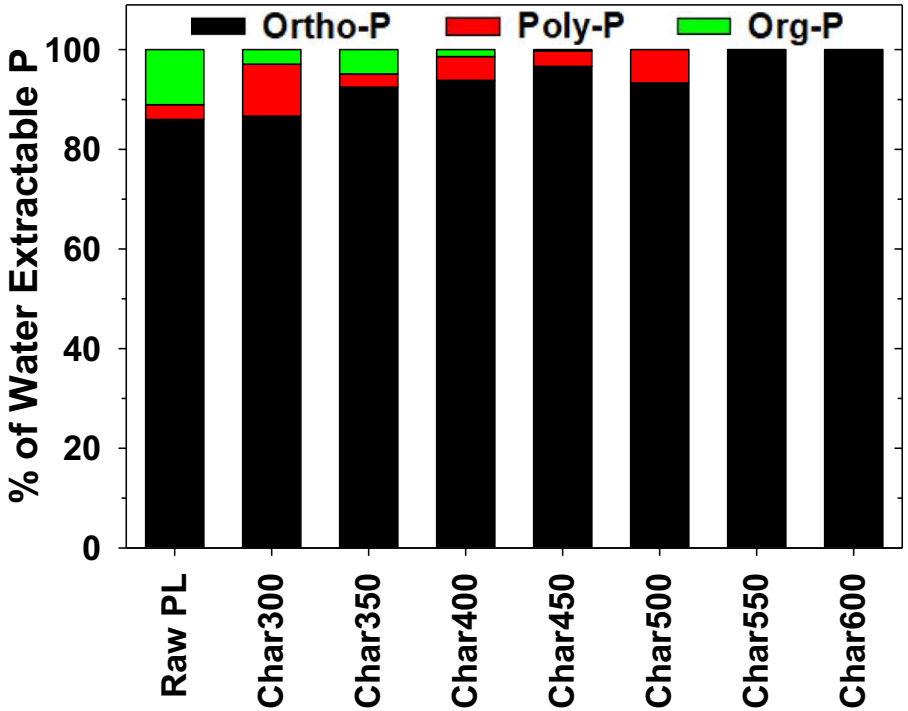
3) Fractionation of P in biochar (by sequential extraction)



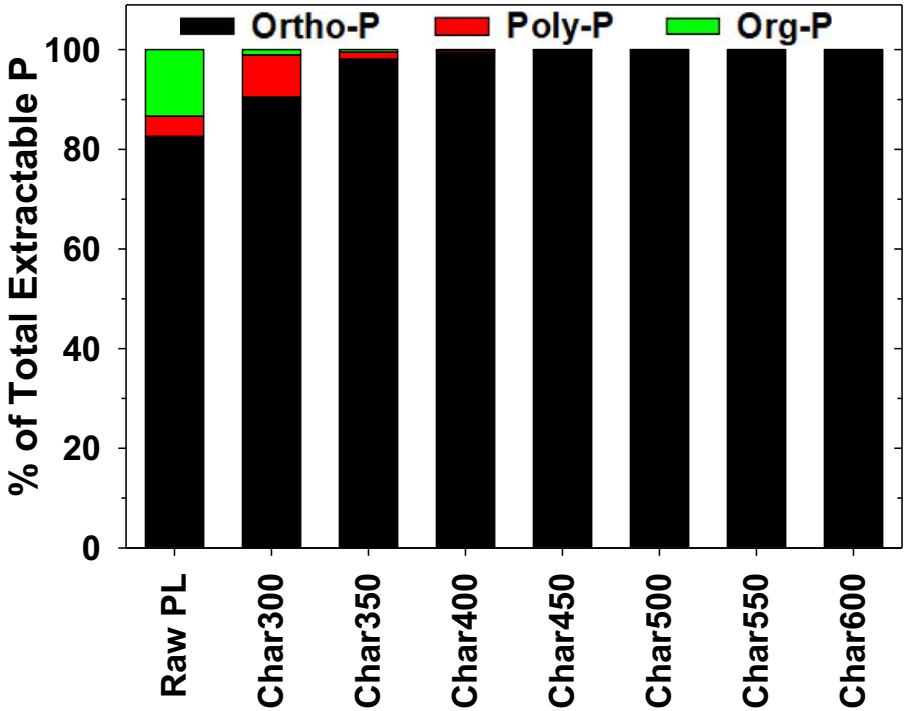
Experiments

Species distribution of extractable P in PL-biochars

Water extractable P

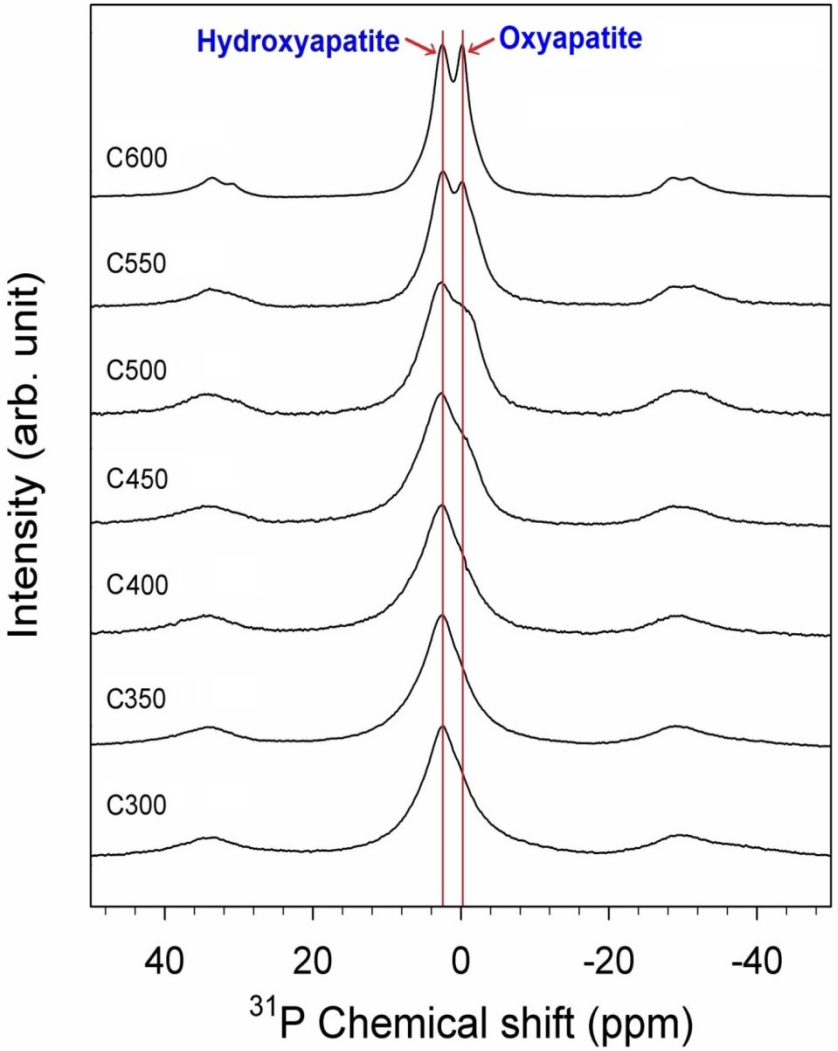


Total extractable P



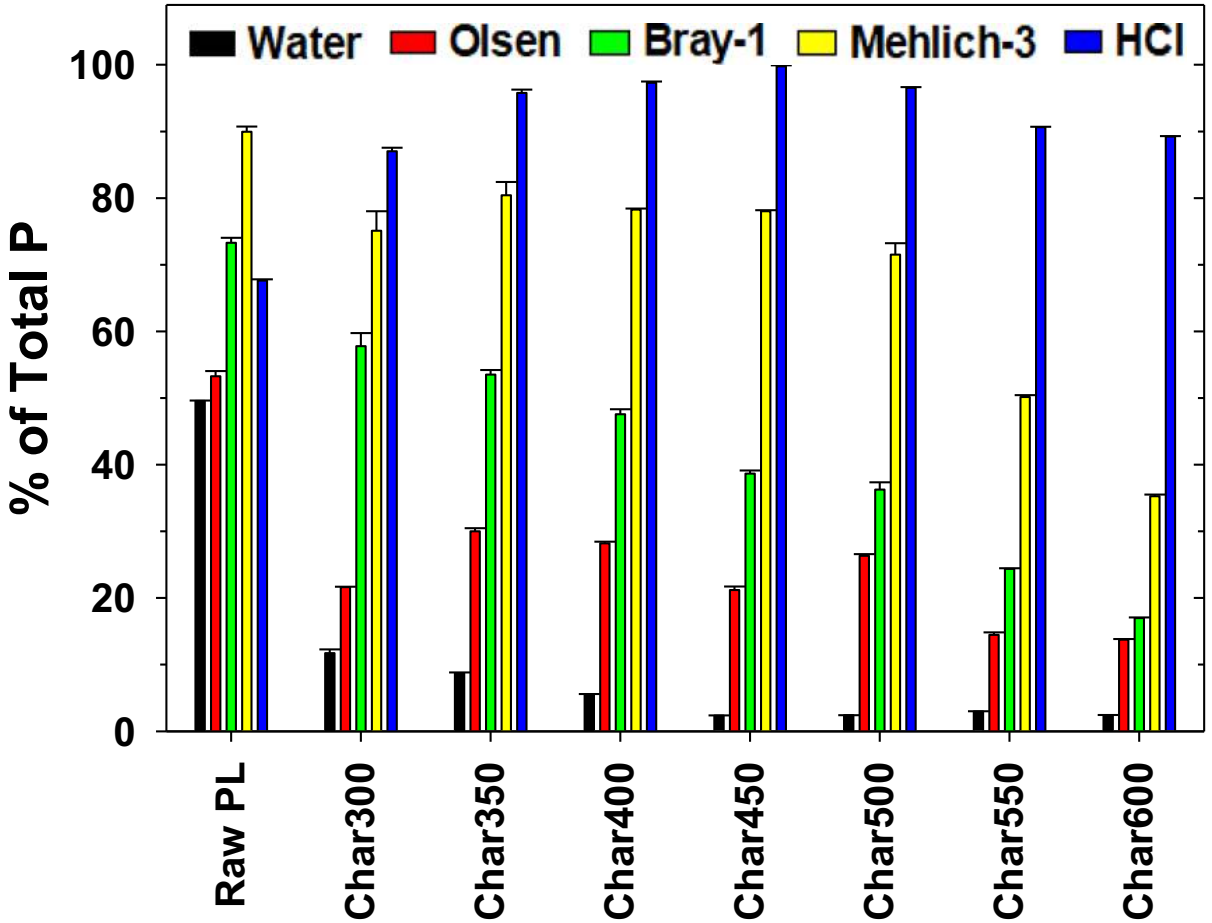
Experiments

^{31}P SP/MAS NMR spectra of PL-biochars



Experiments

4) P Lability of PL-derived biochar



Bray-1

0.025 M HCl in 0.03 M NH_4F

Labile P evaluation

Mehlich-3

NH_4F + EDTA + NH_4NO_3 + HNO_3 + HA)

Long-term available P evaluation

Conclusions

- Loss of N was severe during pyrolytic conversion of PL to biochar, especially at ≥450°C
- During pyrolysis most organic P in PL was converted to inorganic forms mainly as hydroxyapatite and oxyapatite
- Higher-T pyrolysis further reduced the water-extractability and lability of P in PL-biochar
- >70% of P in PL-biochar produced at ≤500°C was Mehlich-3 extractable and phytoavailable
- Low T (350–450°C) was recommended for converting PL to biochar